

# Diarrheal Diseases in Children from a Water Reclamation Site in Mexico City

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This study was conducted to assess the risk of enteric diseases among children living in a water reclamation area in Mexico City. A geographic information system was used to define eligible wells and surrounding homesteads. Sixty-five water samples from five wells were tested for fecal coliform bacteria per 100 mL (FC/100 mL) during visits to 750 eligible households; caretakers only in those dwellings with children under 5 years old were interviewed throughout repeated cross-sectional surveys, conducted during 1999–2000. Data on diarrheal diseases were obtained from 761 children during the rainy season and 732 children during the dry season; their guardians also provided information on drinking water supply, sanitation, and socioeconomic variables. The presence of indicator organisms in groundwater samples pointed to fecal pollution; bacterial indicators, however, did not predict the health risk. The rates of diarrhea were 10.7% in the dry season and 11.8% in the rainy season. Children 1 year old showed the highest rate of diarrhea during the dry season [odds ratio (OR) = 2.1 with 95% confidence interval (CI), 0.99–4.71], particularly those from households perceiving unpleasant taste of tap water (OR, 1.7; 95% CI, 0.97–2.92) and consuming vegetables washed only with water (OR, 2.2; 95% CI, 1.10–4.39). Lower risk was observed in individuals enjoying full-day water supply (OR, 0.5; 95% CI, 0.27–0.86) and a flushing toilet (OR, 0.3; 95% CI, 0.16–0.67), as well as those storing water in covered receptacles (OR, 0.3; 95% CI, 0.15–0.80). Rainy season data suggested that children from households perceiving a color to their water had a higher rate of diarrhea than did those without such complaint (OR, 1.8; 95% CI, 0.93–3.67); recent consumption of food sold by street vendors was also a significant risk factor (OR, 1.6; 95% CI, 0.98–2.87). Groundwater is at risk of contamination, as indicated by the presence of FC/100 mL. The endemic pattern of diarrhea, however, reflects mostly inadequate housing, sanitation, and water-related practices. Health protection policy must be discussed. **Key words:** children's health, environmental risk, water quality indicators. *Environ Health Perspect* 110:A619–A624 (2002). [Online 16 September 2002]

<http://ehpnet1.niehs.nih.gov/docs/2002/110pA619-A624cifuentes/abstract.html>

Water and sanitation deficiencies represent a growing environmental health challenge in several regions around the globe. Unsafe sewage disposal and fecal–oral transmission of pathogens are responsible for otherwise preventable enteric diseases and 3.2 million premature deaths every year (1). In less developed countries, the disease burden falls heavily on the poor (2). This gap is perpetuated by the fact that environmental interventions have neglected sanitary needs and focused on the development of drinking water supplies instead (1,3). Yet the more dramatic “life-saving” oral rehydration salts therapy (an ethical imperative in primary health care) has shifted the attention from the actual role of prevention to cost-effective “solutions” (4). Exposure to fecal pollution is growing as a result of economic driving forces, overcrowded slums, and weak institutions.

The current population of the Mexico City metropolitan area (MCMA) is 18 million and is forecast to be 23.5 million by the year 2015 (5). Up to 75% of its water supply depends on groundwater reserves (6). Overextraction of water has led to soil subsidence and cracking of underground pipes, which may facilitate the mixture of drinking water supplies and sewage, as well as the downward migration of pollutants (7). Earlier

investigations indicated high rates of groundwater positive microbiologic tests (8); despite growing concern, public health data are limited and official reports provide scarcely credible information (9). Additional gaps reflect the limitations of microbial indicators currently used to assess drinking water quality (10); therefore, the basis for “safety” criteria stipulated by national regulations is increasingly debatable (11,12).

A water reuse program, consisting of wastewater treatment and effluent reclamation (e.g., irrigation of fodder and green belts) is being developed in MCMA (13). A series of investigations is being conducted to assess the risk of enteric disease and provide some basis for future environmental interventions. This study addressed the following research questions: Is groundwater microbiologic pollution a health risk? What are the risk factors for enteric diseases? And which further questions should be addressed?

## Methods

The boundaries of Mexico City were first framed within basic geostatistical areas, which in turn were characterized according to demographic variables, as provided by the national census tracks (5). Earlier investigations described the environmental indicators

linked to enteric diseases, from which a “high-risk” communities approach was further developed (14). Our present case study was a second-step approach, resulting from an earlier investigation (14).

The research area is located in Xochimilco, on the outskirts of the city, where a water reclamation project is being developed. This project consists of a series of wastewater treatment plants, the effluents of which flow through a network of canals to be reused for agricultural irrigation, all of which contributes to the recharge of groundwater reserves, for subsequent extraction (i.e., pumping wells).

Eligible study units were homesteads within 500 m of selected wells (Figures 1 and 2). The development of a geographic information system (GIS) allowed for the overlapping of layers containing different data, whereas site visits allowed for the detection of nonresidential units (e.g., farming plots), which were excluded from further consideration. A trained technician gathered a total of 65 water samples from five wells (35 samples during the rainy season and 30 in the dry season). Water samples were collected at a point before chlorination and distribution processing, kept on ice at 4°C, and transported to the laboratory (15). Water samples were incubated 24 hr, and the development of specific color changes (fluorescence) indicated the presence of fecal coliform bacteria (FC/100 mL), which was tested by using the Colilert method (presence/absence), as described by Edberg et al. (16) and approved by the U.S. Environmental Protection Agency. Contaminated wells were defined as those showing positive results in 95% of their water samples, whereas controls were defined as those wells consistently showing negative tests.

Only households having children under 5 years old were numbered and spatially located via GIS. A random sampling technique was used (17), and upon previous informed consent, 750 eligible households were included

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in two repeated cross-sectional studies. A total of 732 children participated in the dry season study (November through May, 1999–2000) and 761 in the rainy season (June through October 2000). Trained field workers used structured questionnaires to gather data on episodes of diarrhea, and the recall period was the preceding week, as recommended by the World Health Organization (18). The guardian (i.e., mother) also provided information on housing characteristics (e.g., water supply, sanitation, hygiene, and socioeconomic-related variables).

**Data management and analysis.** Both environmental and population data were entered twice and error corrected. IBM-compatible computers (486 processors) were used. For population data, the unit of analysis was the individual. Each child was allocated to one water quality category, which remained constant throughout the analysis; children exposed to different wells were allocated to the highest exposure. An episode of diarrhea (health outcome) was defined as three or more loose stools in 24 hr. Potential confounding

factors were included in the analysis; crowding (proxy of low socioeconomic strata) was incorporated as a continuous variable (three to six individuals per bedroom), and the odds ratio was interpreted as the excess of disease among children living in crowded dwellings, when compared with children without this factor (i.e., < 3 individuals). Special attention was paid to seasonal differences (19), and every independent variable showing significant association (Pearson chi-squared test) with diarrheal diseases was included in the final model. Statistical analysis was performed by using multiple logistic regression techniques (20).

Disease prevalence rates, odds ratios (OR), 95% confidence intervals (95% CI), and *p*-values were the measurements employed, by using STATA (21) and SPSS (22). Both the environmental and health risk data were overlapped by using GIS, and MapInfo software was used (23).

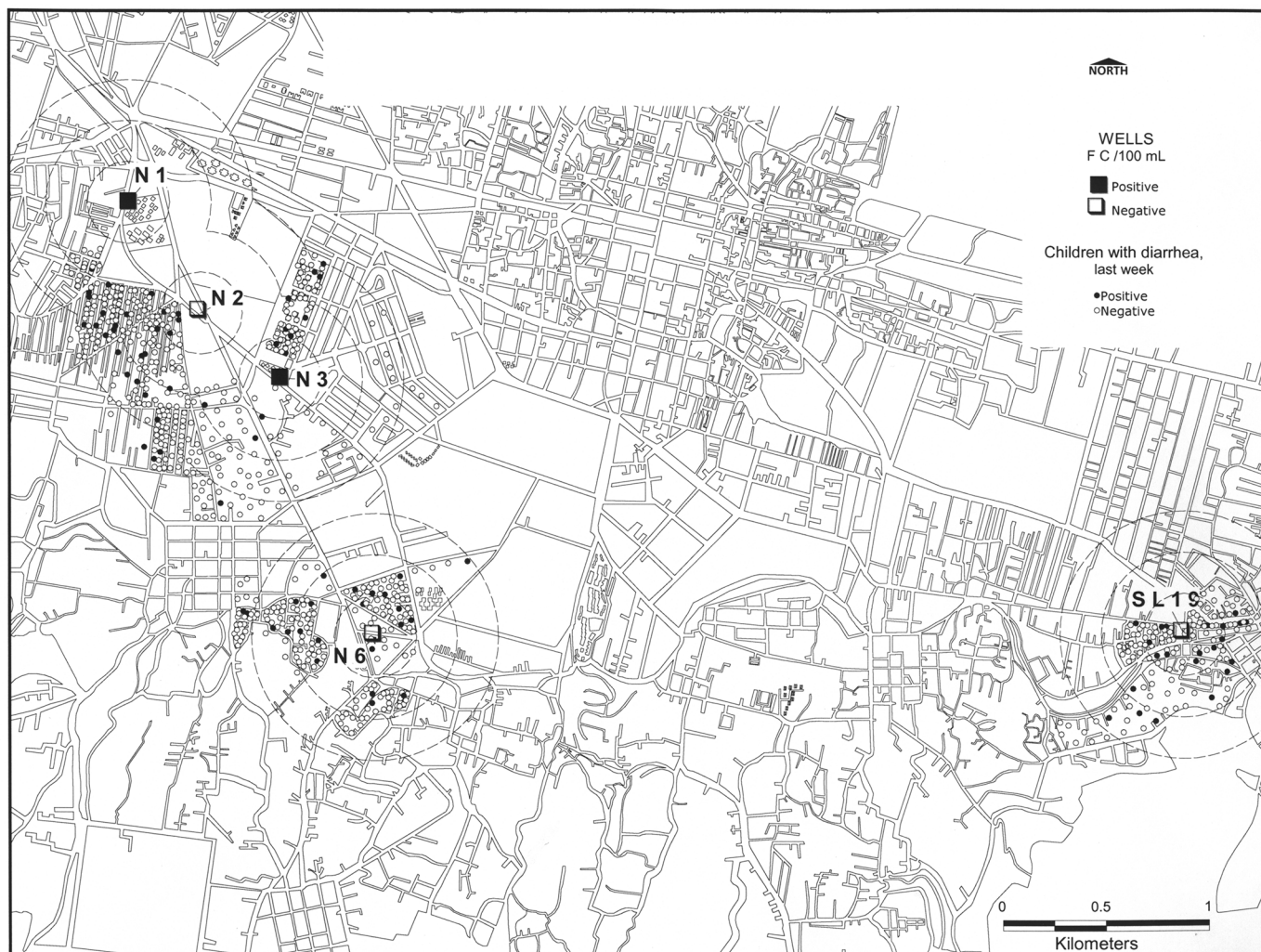
## Results

Table 1 illustrates the characteristics of the population. The prevalence rates of diarrhea

were 10.7% in the dry season and 11.8% in the rainy season. Crowding conditions were detected in more than half of the dwellings visited. Three-quarters of the children came from households with piped water supply inside their dwelling; for more than 60% of these, however, water supply failures (> 12 hr/day) were a common experience. Data showed that drinking water was usually stored in unprotected tanks and buckets (29–33%). When respondents were questioned about perceived characteristics of tap water, a third of them reported unpleasant taste; a similar proportion reported purchasing commercially bottled water, particularly during the dry season.

Water quality and spatial location of children are shown in Figures 1 and 2. Wells N1 and N3 showed the presence of bacterial indicator (FC/100 mL), whereas wells N2, N6, and SL19 showed consistently negative results (i.e., absence of bacteria).

Bivariate analysis (Table 2) showed no statistical association between the presence of bacterial indicators (FC/100 mL) in water



**Figure 1.** Water microbiologic quality and enteric diseases, dry season, Xochimilco, 2000.

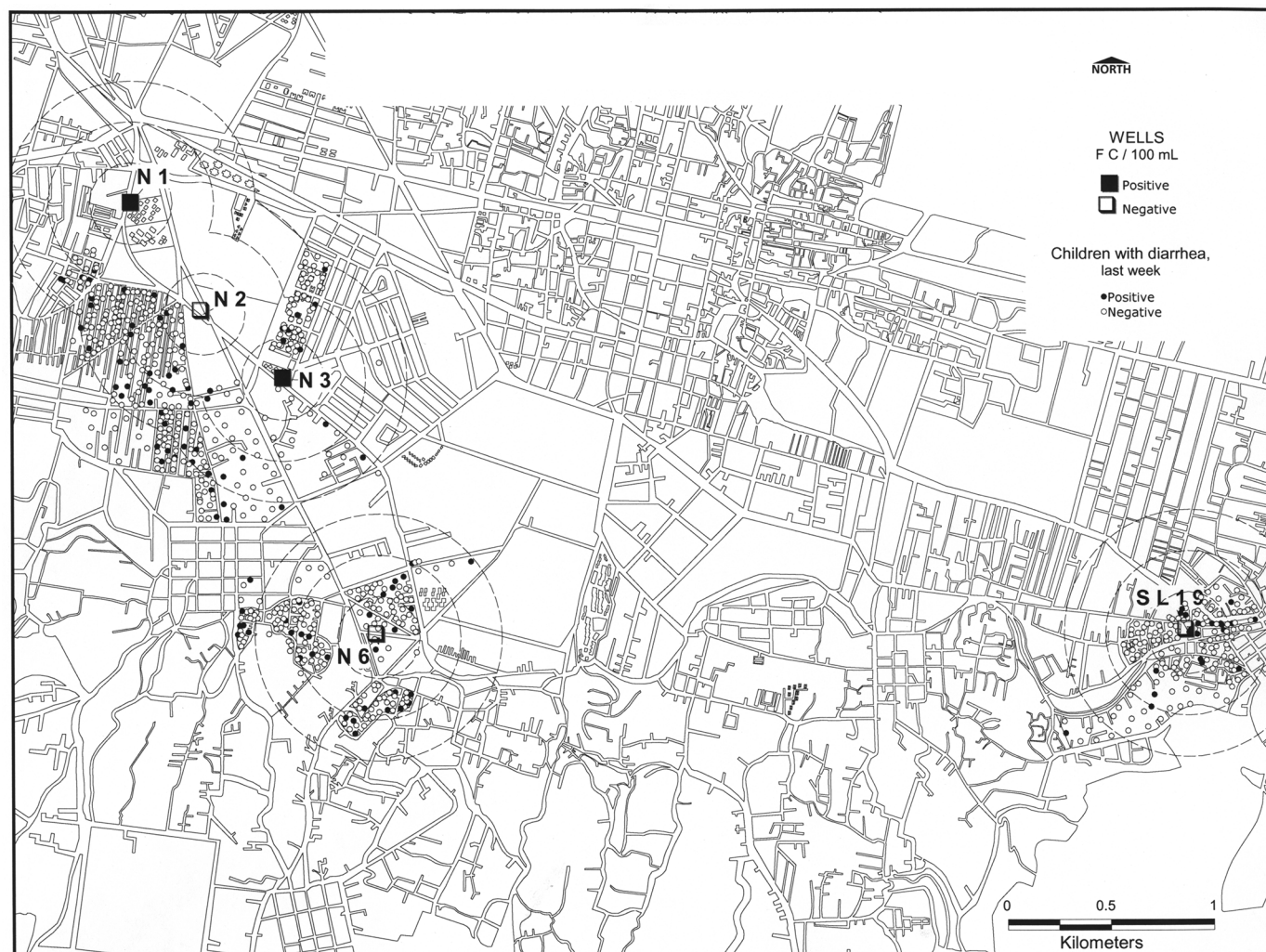


samples and risk of enteric diseases (OR = 0.7 in the dry season and OR = 1.1 in the rainy season). As data illustrate, longer episodes of diarrhea were detected in the dry season than during the rainy season (OR, 3.7; 95% CI, 1.39–10.08), particularly among individuals between their first and second birthday (22.6%; OR, 2.1; 95% CI, 1.03–4.50). The lowest prevalence of diarrhea was detected in older children (7.7% and 9.5%), although this observation was statistically significant only in the wet season study (OR, 0.5; 95% CI, 0.26–0.94). The prevalence of diarrhea was higher among children from households without piped water than among children in households with it (18.5% and 8.1%, respectively), and this association was detected only in the dry season (OR, 2.5; 95% CI, 1.58–4.18). Children from households complaining of unpleasant taste of water had a higher risk than did children from households without such complaint (OR, 1.7; 95% CI, 1.04–2.70 in the dry season; OR, 1.5; 95% CI, 0.95–2.33 in the rainy season), whereas perceived color of water was

statistically significant only in the rainy season (OR, 1.9; 95% CI, 0.97–3.74) and not in the dry season, when a 2-fold risk was observed among children from dwellings without water for flushing the toilet (OR, 2.1; 95% CI, 1.32–3.41), as well as from dwellings where water was stored in unprotected buckets or cisterns (OR, 1.9; 95% CI, 1.04–3.42) and with no hand-washing habits (OR, 1.7; 95% CI, 0.95–3.13). Children from households whose members held cultural explanations of diarrhea had a higher risk of diarrhea than did children in households with beliefs regarding food and water pollution or hygiene (OR, 1.9; 95% CI, 1.05–3.70). Children who had recently consumed food sold by street vendors had a higher rate of diarrhea than did those who did not, although this association was found only during the wet season (OR, 1.7; 95% CI, 0.99–2.87). A health risk was also detected in children living in crowded dwellings (OR, 1.2; 95% CI, 1.03–1.50), although this association was observed only during the dry season.

Logistic regression analysis (Tables 3 and 4) confirmed a lack of statistical association between the presence of fecal coliform bacteria in groundwater samples and health risk. The final analyses showed that the highest prevalence of diarrhea affected children 1–2 years old, whereas a decreasing risk was observed in older children; in the younger children, the difference was statistically significant in the dry season (OR, 2.1; 95% CI, 0.99–4.71), whereas the lower risk in older children was observed only during the wet season (OR, 0.5; 95% CI, 0.26–0.95).

Dry season data (Table 3) showed that children from households perceiving unpleasant taste of water had a higher risk than did children in households without such complaint (OR, 1.7; 95% CI, 0.97–2.92). In addition, a 2-fold risk was observed in children from households in which vegetables are usually washed only with tap water before consumption, compared with households using chlorine for disinfection or soap (OR, 2.2; 95% CI, 1.10–4.39). In contrast, protective associations were observed among children



**Figure 2.** Water microbiologic quality and enteric diseases, rainy season, Xochimilco, 2000.

**Table 1.** General characteristics of the study population.

Characteristics	Dry season ( <i>n</i> = 732)		Rainy season ( <i>n</i> = 761)	
	No.	Percent	No.	Percent
Prevalence of acute diarrhea (last week)	78	10.7	90	11.8
Piped water supply inside the dwelling				
No	178	24.3	178	23.4
Yes	554	75.7	583	76.6
Full-day water supply				
No	488	66.7	486	63.9
Yes	244	33.3	275	36.1
Taste of water				
No	492	67.2	487	64.0
Yes	240	32.8	274	36.0
Storage of drinking water				
Commercially bottled	200	27.4	159	20.9
Covered jar	224	30.6	235	30.9
Unprotected cistern, bucket	217	29.6	251	33.0
Protected cistern, bucket	91	12.4	116	15.2
Availability of water for toilet flushing				
No	488	63.8	440	59.4
Yes	244	36.2	301	40.6
Crowding (> 2 persons/bedroom)				
No	332	45.4	289	38.0
Yes	400	54.6	472	62.0

from households with full-day water supply (OR, 0.5; 95% CI, 0.27–0.86) and having a flushing toilet (OR, 0.3; 95% CI, 0.16–0.67) and a shower inside the dwelling (OR, 0.4; 95% CI, 0.23–0.96). A similar pattern was detected for storing water in covered jars (OR, 0.3; 95% CI, 0.15–0.80).

Rainy season data (Table 4) showed that children from households complaining of drinking water color had a higher prevalence of diarrhea than did those in households without it (OR, 1.8; 95% CI, 0.93–3.67). Recent consumption (i.e., preceding week) of food from street vendors was also observed to represent a health risk (OR, 1.6; 95% CI, 0.98–2.87).

## Discussion

This investigation suggested an endemic pattern of enteric diseases, rather than a water-borne outbreak; the rates of diarrhea were not substantially different from the ones recently reported for Mexico as a whole (24). Equally

**Table 2.** Bivariate analysis: risk factors for diarrheal diseases in children.

Risk factors	Dry season						Rainy season					
	<i>N</i>	Percent	<i>n</i>	OR	95% CI	<i>p</i> -Value	<i>N</i>	Percent	<i>n</i>	OR	95% CI	<i>p</i> -Value
Well water quality (FC/100 mL)												
Clean	428	11.6	50	1			574	11.4	66	1		
Contaminated	304	9.2	28	0.7	0.47–1.25	0.28	187	12.8	24	1.1	0.69–1.87	0.62
Age of children												
< 1 year	101	11.8	12	1			80	17.5	14	1		
1–2 years	115	22.6	26	2.1	1.03–4.50	0.04	125	18.4	23	1.0	0.51–2.12	0.87
> 2 years	516	7.7	40	0.6	0.31–1.23	0.17	556	9.5	53	0.5	0.26–0.94	0.03
Duration of diarrheal episode												
1 day	25	56.0	14	1			27	81.4	22	1		
≥ 2 days (< 8 days)	75	82.6	62	3.7	1.39–10.08	0.01	90	71.1	64	0.5	0.19–1.63	0.29
Piped water inside the dwelling												
Yes	554	8.1	45	1			583	11.1	65	1		
No	178	18.5	33	2.5	1.58–4.18	0.00	178	14.0	25	1.3	0.79–2.13	0.29
Hand washing												
Yes	631	9.8	62	1			110	14.5	16	1		
No	101	15.8	16	1.7	0.95–3.13	0.07	651	11.3	74	0.7	0.42–1.34	0.34
Taste of water												
No	492	8.9	44	1			487	10.2	50	1		
Yes	240	14.1	34	1.7	1.04–2.70	0.03	274	14.5	40	1.5	0.95–2.33	0.07
Color of water												
No	679	10.1	69	1			699	11.1	78	1		
Yes	53	16.9	9	1.8	0.84–3.86	0.12	62	19.3	12	1.9	0.97–3.74	0.05
Availability of water for toilet flushing												
Yes	467	7.9	37	1			440	12.0	53	1		
No	265	15.4	41	2.1	1.32–3.41	0.02	301	11.3	34	0.93	0.58–1.46	0.75
Storage of drinking water												
Commercially bottled	200	9.5	19	1			159	10.6	17	1		
Covered jar	224	5.3	12	0.5	0.25–1.14	0.10	235	13.6	32	1.3	0.70–2.46	0.38
Unprotected cistern or bucket	217	16.5	36	1.9	1.04–3.42	0.03	251	12.3	31	1.1	0.62–2.20	0.61
Protected cistern or bucket	91	12.0	11	1.3	0.59–2.88	0.50	116	8.6	10	0.8	0.34–1.79	0.56
Consumption of fast food/street-vendor products												
No	217	7.8	17	1			228	8.3	19	1		
Yes	515	11.8	61	1.6	0.90–2.77	0.11	533	13.3	71	1.7	0.99–2.87	0.05
Perceived "cause" of diarrhea												
Poor hygiene	222	8.1	18	1			272	12.5	34	1		
Water and food	328	10.0	33	1.2	0.69–2.31	0.43	312	9.9	31	0.7	0.46–1.30	0.32
Cultural syndromes (e.g., evil eye)	182	14.8	27	1.9	1.05–3.70	0.03	177	14.1	25	1.1	0.66–2.00	0.61
Crowding (> 2 persons/bedroom)*												
Yes	400	12.0	48	1.2	1.03–1.50	0.03	476	1.1	462	11.9	0.91–1.29	0.41

Abbreviations: *N*, total number of children in category; *n*, number of infected children (positive test). \*Continuous variable.

important, perhaps, the water quality indicators used did not predict the health risk. It is necessary to emphasize, however, that groundwater is in jeopardy, and this could be the actual meaning of the presence of bacteria in water samples. Despite the lack of statistical association between groundwater quality and health risk, it is worth emphasizing that fecal pollution is finding its way to underground water sources. This observation may be different from official reports.

As expected, the rate of enteric disease was slightly higher in the wet season; more risk factors, however, were detected during the driest time of the year. These observations are not new, but reinforce the following points: The high prevalence of diarrhea detected in children within the first months after birth (rainy season) and a 2-fold risk in

older children (dry season) may be suggesting different enteric syndromes with possible seasonal influences. The whole picture simply confirmed that housing deficiencies, hygiene-related behavior (including food), water storage practices, and risk perceptions were all at play (25–27).

Interestingly, children from households complaining of unpleasant attributes of water (e.g., taste, color), as well as those stating culturally influenced beliefs in disease etiology (e.g., evil eye), had a higher risk of diarrhea than did those without complaints and giving hygiene-related answers to questions regarding beliefs. Similar observations were reported by Whiteford (28) studying the ethnoecology of water-based diseases in the Caribbean; our work reinforces the relevance of perception data in environmental research.

Our study has limitations that must be taken into account. First, eligible households were confined to less than 500 m around each well, assuming that children were not exposed to “distant” wells, which may or may not be the case. Second, and equally important perhaps, groundwater samples were obtained before the water passed through the chlorination device, and therefore microbiologic results did not reflect directly the quality of water flowing through the distribution pipes and reaching the consumers; financial and logistical constraints prevented house-to-house tap sampling. Third, as the data illustrate, more than a third of this population reported current consumption of commercially bottled water, whereas direct ingestion from the tap was seldom reported.

Methodologic shortcomings may also result from the cross-sectional study design, which does not prove cause and effect. It must be stated, however, that more than 75% of children involved were evaluated during both seasons (the rest were replaced from within the same compound). Furthermore, the involvement of a control group, the fact that water quality data were unknown to interviewers and respondents, the use of an operationally defined health outcome, and the procedures used to control for potentially confounding factors (e.g., socioeconomic status) during the analysis all reduced the chances of bias.

Final comments refer to future environmental health research: The challenge of detecting “waterborne” diseases represents a major issue, because methodologies are rather insensitive, laborious, expensive, and/or time-consuming. It must be emphasized that many intestinal infections may show few clinical symptoms, and outbreaks may not be detected. Previous exposure to enteric pathogens may alter a subject's clinical response, often reducing the severity of illness; when pathogens are endemic, much of the population may become immune. On the other hand, if pathogens are removed from drinking water (“zero” risk), the population may become increasingly susceptible (12).

Health policy should reflect worldwide evidence that removal of coliform bacteria, widely used as a water quality indicator, is not enough to exclude health risk. The interpretation of the safety threshold (i.e., absence of FC/100 mL) requires further discussion, particularly in water reclamation scenarios. Earlier screening in our setting has detected *Giardia intestinalis* cysts and *Cryptosporidium parvum* oocysts in the water treatment plant effluents that comply with current quality guidelines (no detectable FC/100 mL). New studies are being conducted to address the question of risk from protozoal infection, and these results will be presented in future communications.

**Table 3.** Logistic regression analysis: risk factors for diarrheal diseases, dry season.

Variables	N	Percent	n	OR	95% CI	p-Value
Well water quality						
Clean	428	11.7	50	1		
Contaminated	304	9.2	28	1.0	0.58–1.75	0.96
Age of children						
< 1 year	101	11.9	12	1		
1–2 years	115	22.6	26	2.1	0.99–4.71	0.05
> 2 years	516	7.8	40	0.6	0.29–1.22	0.15
Full-day water supply						
No	488	11.9	58	1		
Yes	244	8.2	20	0.5	0.27–0.86	0.01
Taste of water						
No	492	8.9	44	1		
Yes	240	14.2	34	1.7	0.97–2.92	0.06
Place for bathing						
Tap, yard outside	432	9.5	41	1		
Shower, bathroom	300	12.3	37	0.4	0.23–0.96	0.03
Storage of drinking water						
Commercial bottle	200	9.5	19	1		
Covered jar	224	5.4	12	0.3	0.15–0.80	0.01
Unprotected cistern or bucket	217	16.6	36	1.3	0.63–2.76	0.45
Protected cistern or bucket	91	12.1	11	0.9	0.38–2.19	0.84
Availability of water for toilet flushing						
No	265	15.5	41	1		
Yes	467	7.9	37	0.3	0.16–0.67	0.002
Vegetable hygiene						
Disinfection, chlorine	216	6.5	14	1		
Water and soap	267	11.2	30	1.7	0.85–3.43	0.13
Only water	249	13.7	34	2.2	1.10–4.39	0.02

Abbreviations: N, total number of children in category; n, number of infected children (positive test).

**Table 4.** Logistic regression analysis: risk factors for diarrheal diseases, rainy season.

Variables	N	Percent	n	OR	95% CI	p-Value
Well water quality (FC/100 mL)						
Clean	574	11.5	66	1		
Contaminated	187	12.8	24	1.1	0.69–1.75	0.68
Age of children						
< 1 year	80	17.5	14	1		
1–2 years	125	18.4	23	1.0	0.50–2.21	0.88
> 2 years	556	9.5	53	0.5	0.26–0.95	0.03
Color of water						
No	699	11.2	78	1		
Yes	62	19.4	12	1.8	0.93–3.67	0.08
Consumption of fast food/ street-vendor products						
No	228	8.3	19	1		
Yes	533	13.3	71	1.6	0.98–2.87	0.06

Abbreviations: N, total number of children in category; n, number of infected children (positive test).



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